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ACCEPTABLE LIMITS OF ROTATING BAND DAMAGE FOR 5 INCH PROJECTILES

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FOREWORD

This study was conducted as a result of needs to quantify acceptable magnitudes of damage to rotating bands. It is part of the projectile design agent work being done at NSWC. The main purpose was to determine the effect of a damaged rotating band of a projectile upon its ballistic performance. Results of this study can be used as a guideline to quantify acceptable magnitudes of rotating band damage as a result of handling and workmanship.

This report was reviewed by the following:
R. W. Lowry - NSWC Design Agent Program Manager
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ABSTRACT

Twenty 5"/54 MARK 64 MOD 0 projectiles with various degrees of rotating band damage were ballistic tested. A control group with no rotating band damage was tested along with several other groups with nicks, scratches, and gouges in the rotating bands. None of the groups gave ballistic results (velocity or range) significantly different from the control group or each other. Photographs show acceptable levels of rotating band damage with respect to ballistic performance.

CONTENTS

I. INTRODUCTION

Damaged copper or gilding metal rotating bands have been of great concern in the ammunition discipline for some time. NSWC has received numerous verbal and written requests to quantify acceptable limits of damage to rotating bands for 5" ammunition. The most recent request was reference (a). A naval speedletter, reference (b), was an interim reply to reference (a) and gave tentative guidelines as to acceptable damaged rotating bands. Reference (c) gave more specific guidelines and reported the work herein in abbreviated form. This report is a detail documentation of the guidelines given in reference (c).

Rotating band damage generally occurs during handling. Projectiles can be dropped, bounced against each other, or other means to incur damage to the rotating band. The high lip is especially susceptible to damaging during handling or even during fabrication of the projectile. Most serious type damages generally occur at ammunition depots or aboard ships.

II. DESCRIPTION OF MATERIAL

The projectile bodies used in this study were fabricated by American Manufacturing Company of Texas (AMCOT), Fort Worth, Texas. They are 5"/54 MARK 64 MOD 0 projectiles which were sampled from production lots for acceptance tests at NSWC. Figure 1 shows the projectile body configuration and a detail sketch of the rotating band in View A. Rotating bands for this projectile are made from gilding metal (90% Cu - 10% Zn).

Twenty projectile bodies were selected from stocked acceptance rounds at NSWC. These projectiles had rotating bands free of damages. The 20 projectiles were numbered 1-20 for identification. They were then divided into 10 test groups (conditions) labeled T1-T10 with two projectiles randomly assigned to each test group. These 10 test groups composed various types and magnitudes of artificially created rotating band damage (worse than normally encountered). Cross section views of the rotating band damage are shown in Figure 2 for each group that is identified below:

Test Group	Type of Surface Flaw in Rotating Band	Notes
T1	None	Control group
T2	One high lip nick ".020 deep	See Figure 3
T3	One high lip nick ".040 deep	See Figure 4
T4	Two high lip nicks each ".020 deep	Same as shown in Figure 3 except there were two nicks 180° apart
T5	Two high lip nicks each ".040 deep	Same as shown in Figure 4 except there were two nicks 180° apart
T6	Four high lip nicks each ".040 deep	Same as shown in Figure 4 except there were four nicks 90° apart
T7	Two scratches each ".035 deep x 1/8" wide across entire band	As shown in Figure 5 except there were two scratches 180° apart
T8	Two scratches each ".070 deep x 1/8" wide across entire band	As shown in Figure 6 except there were two scratches 180° apart

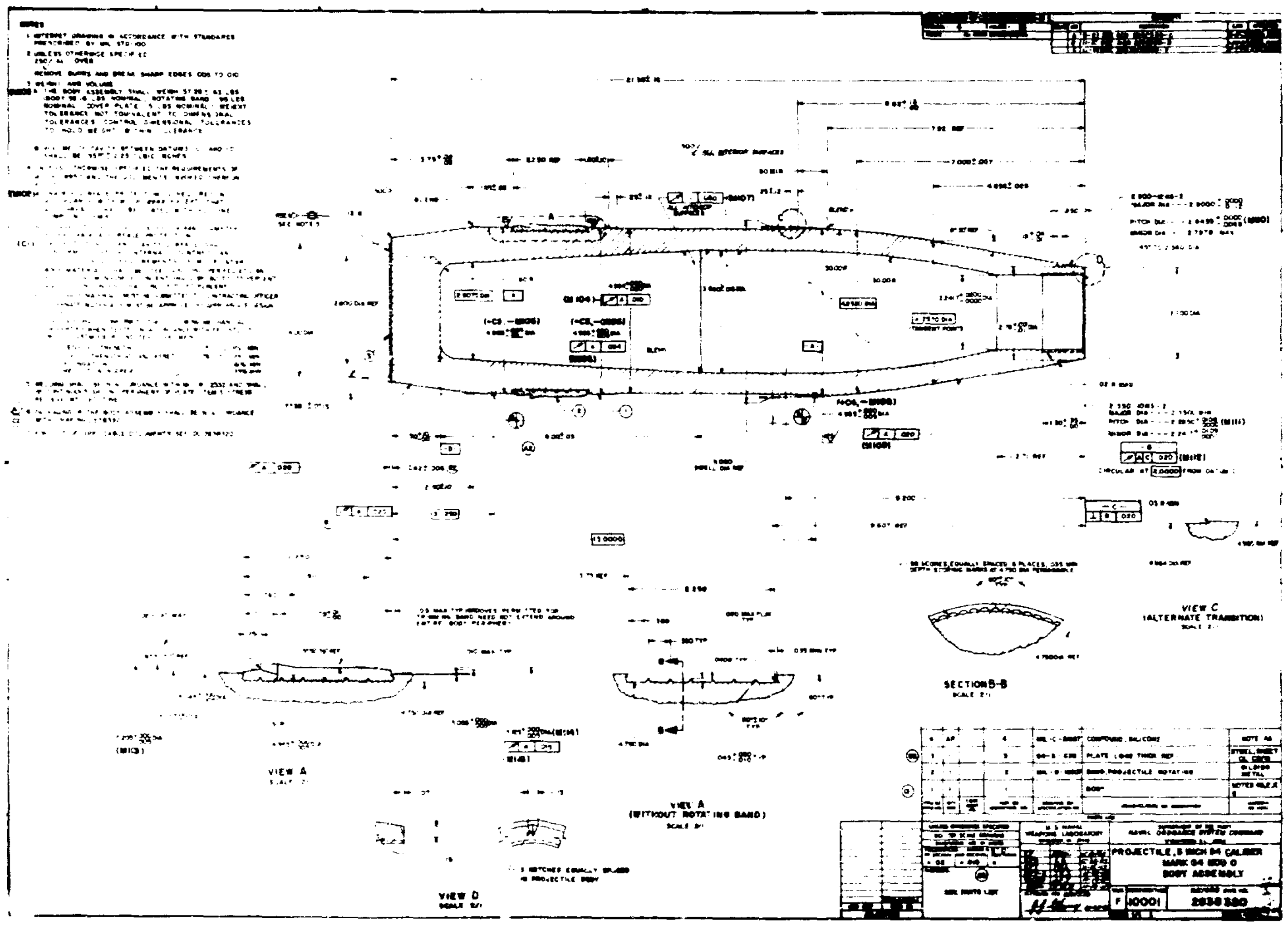

FIGURE 1

Drawing of 5"/54 MARK 64 MOD 0 Projectile Body

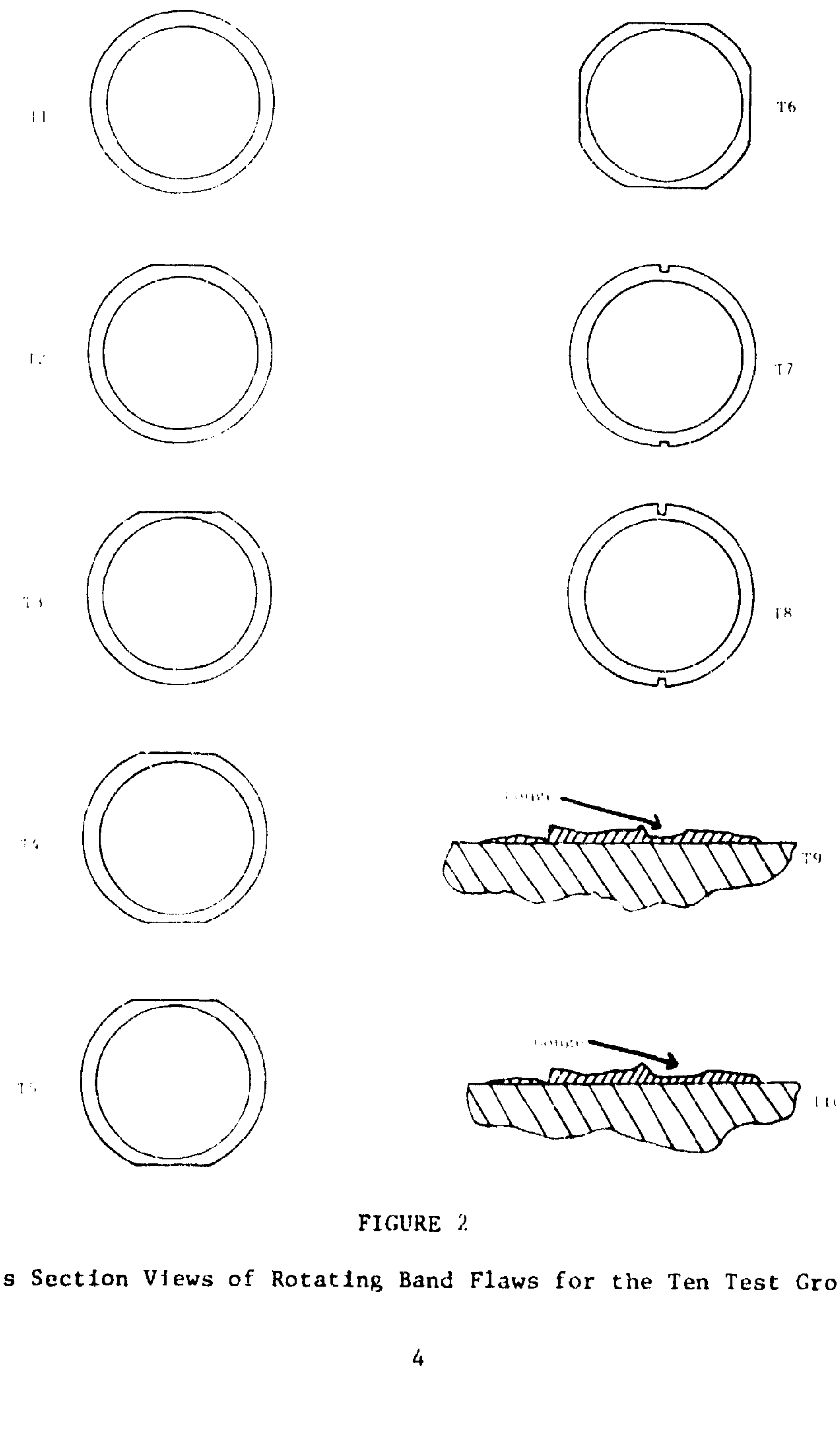

FIGURE 2

Cross Section Views of Rotating Band Flaws for the Ten Test Groups

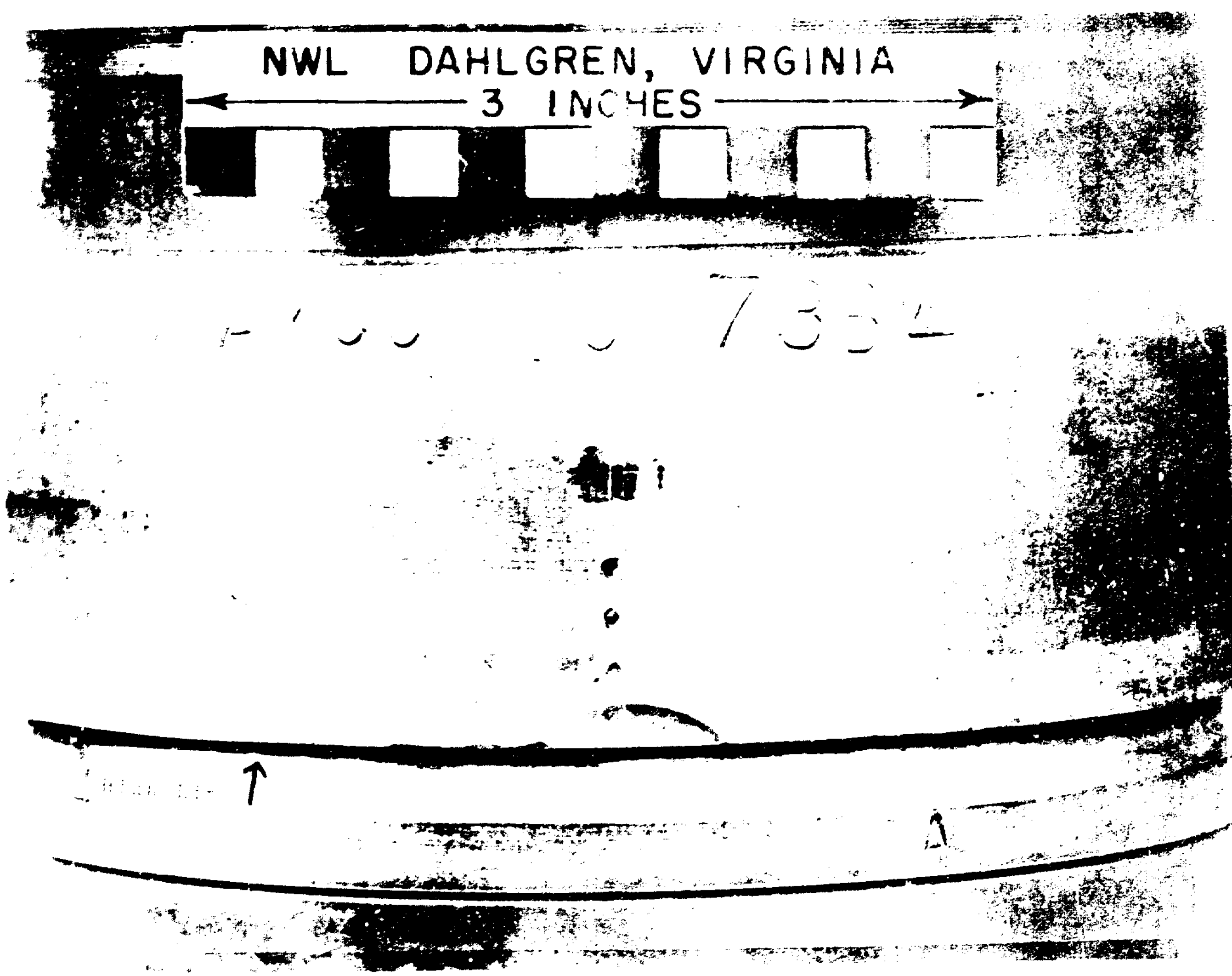

FIGURE 3

View of a Rotating Band with a High Lip Nick 0".020 Deep

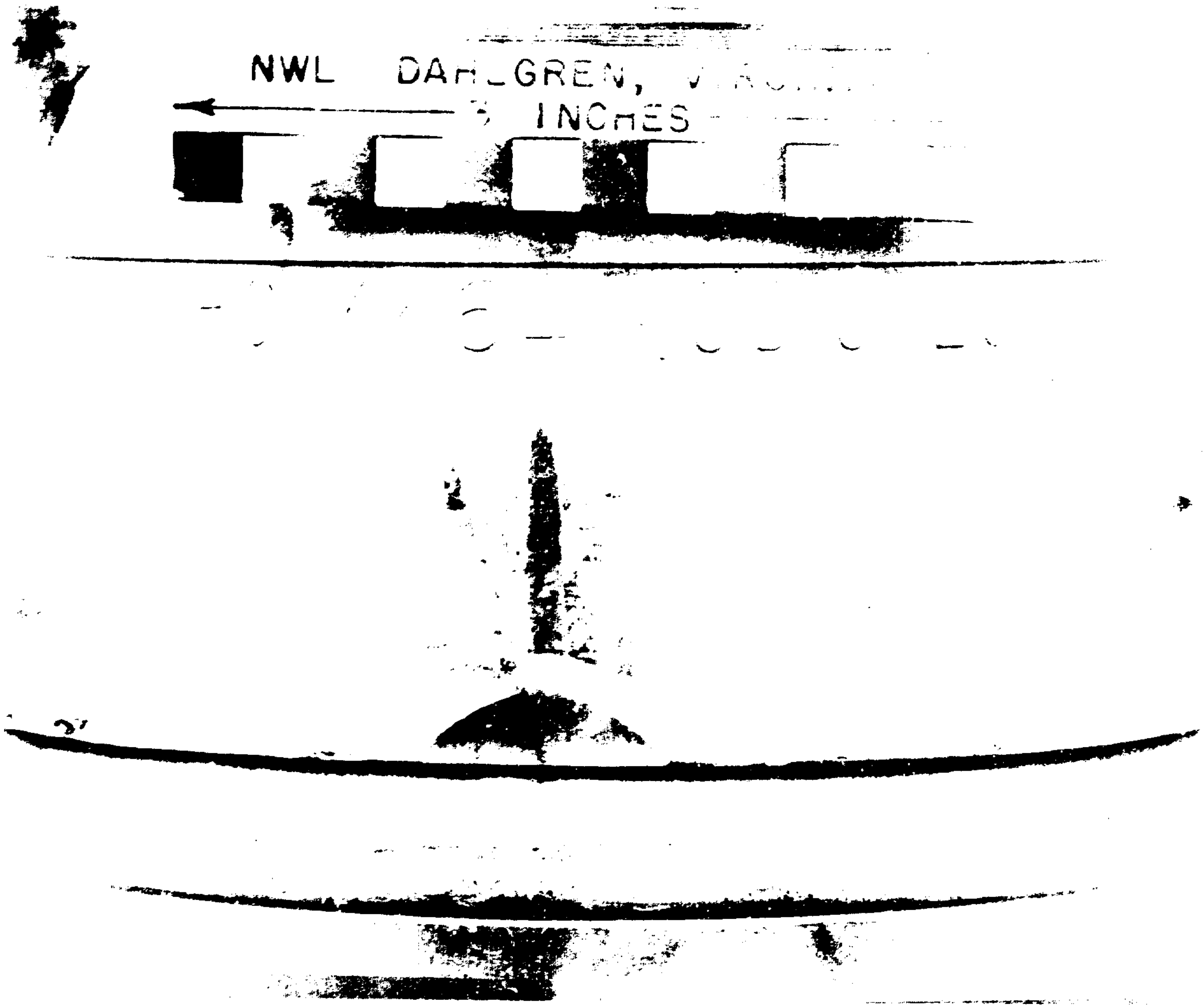

FIGURE 4

View of a Rotating Band with a High Lip Nick 0.040 Deep

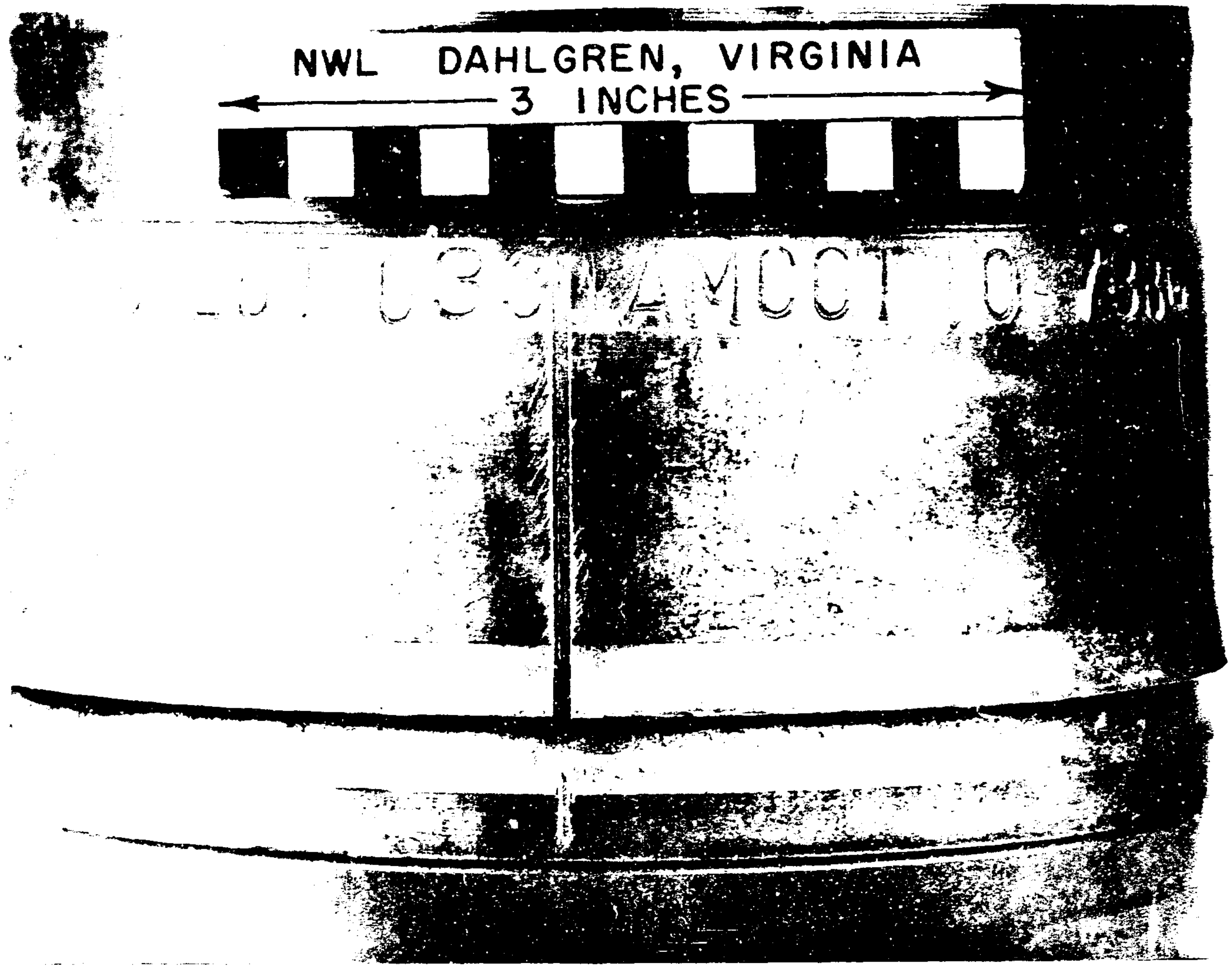

FIGURE 5

View of a Rotating Band with a Scratch 0.035 Deep

FIGURE 6

View of a Rotating Band with a Scratch 0."070 Deep

Test Group	Type of Surface Flaw in Rotating Band	Notes
T9	One gouge ".5 wide	See Figure 7
T10	One gouge 1".0 wide	See Figure 8

High lip nicks and scratches were machined on the rotating bands with an end mill. Gouges were placed in the rotating bands with a 1/2" and 1" cold chisel. Projectiles were placed on v blocks at the bourrelets to facilitate grinding the nicks and scratches. All depths were measured from the top of the high lip for nicks and scratches.

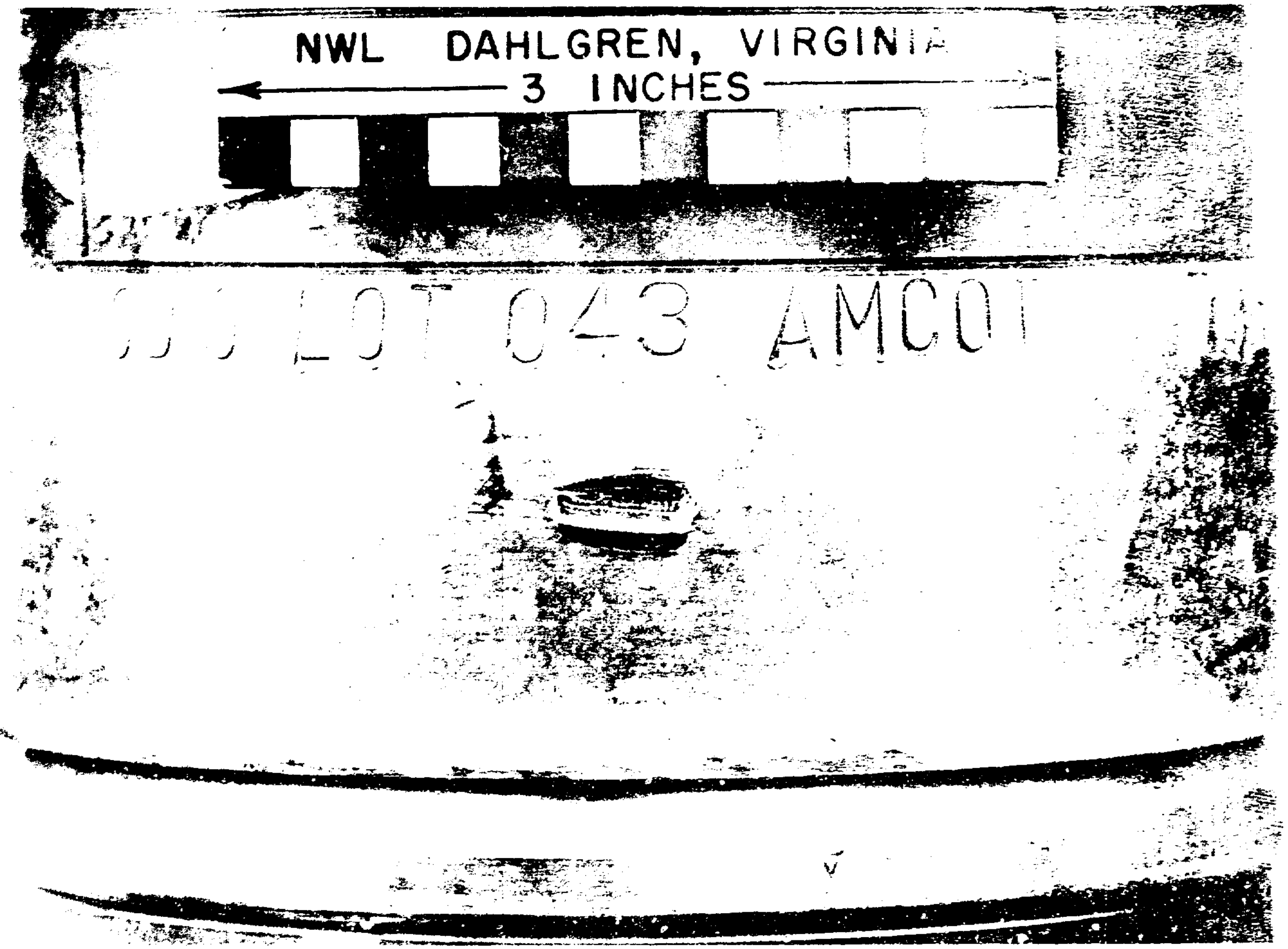

FIGURE 7

View of a Rotating Band with a 0"5 Wide Gouge

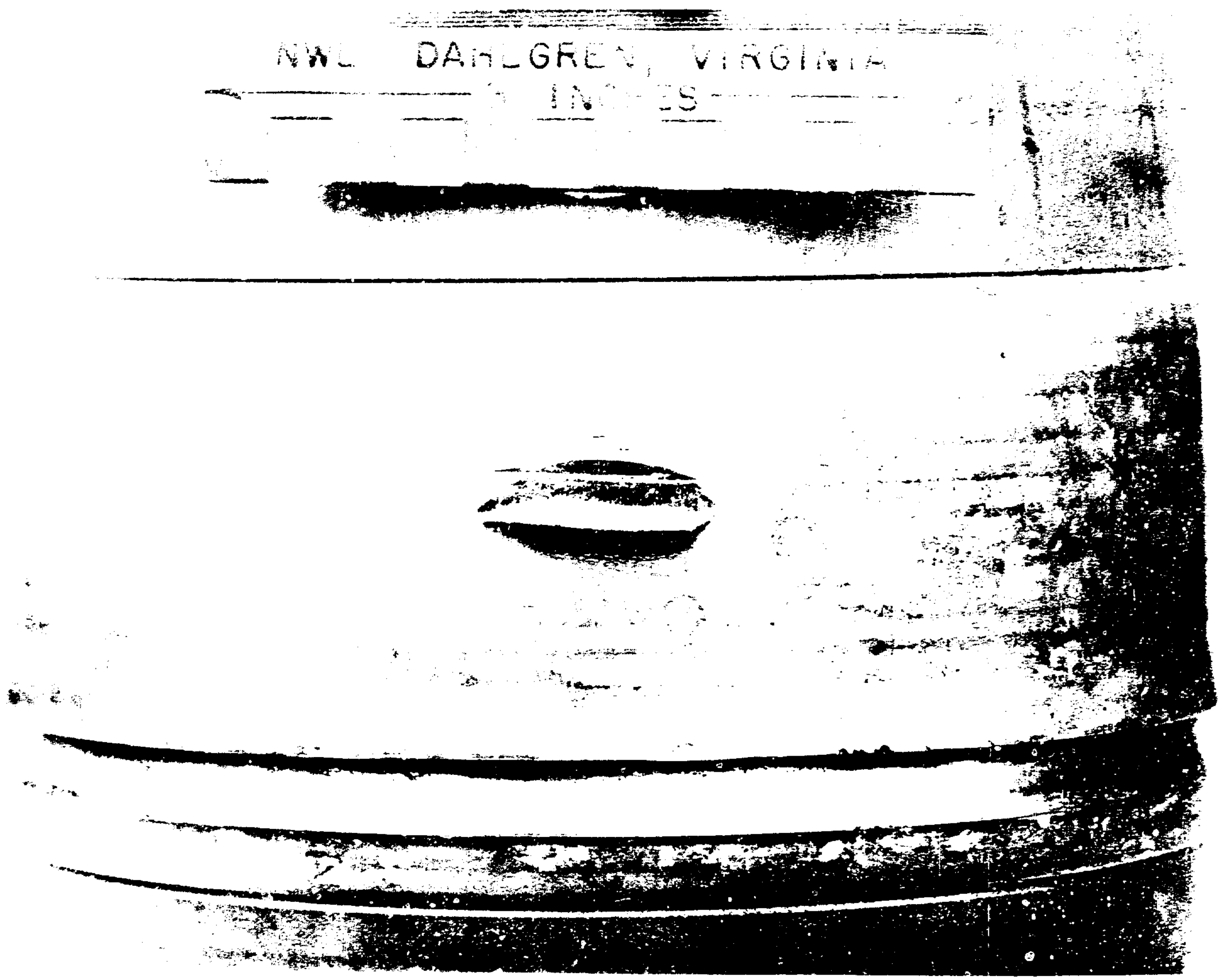

FIGURE 8

View of a Rotating Band with a 1.0" Wide Gouge

III. TESTS AND PROCEDURES

The 20 projectiles (10 test groups) were ballistically tested comparable to standard acceptance tests of projectiles at NSWC. Two projectiles were of each test group (T1-T10). All tests were conducted within 50 minutes on the same day (15 May 1974). Propellant index number SPCF-11157 (NACO Flashless) was used for all tests. A 5"/54 MARK 18 MOD 1 gun (number 16275) was used at a 15° elevation. This gun was in the third quarter gun wear life.

The projectiles were inert loaded with a filler to simulate an explosive to produce a weight of 70.00 pounds. A dummy fuze was installed on the nose of the projectiles.

Ballistic tests were conducted in a random order as given in Table 1 so as to average out unknown effects. Initial velocity, seating distance, and range were measured and are given in Table 1. Initial velocity was measured by the coil method and range by standard spotting procedures at NSWC.

TABLE 1

SUMMARY OF BALLISTIC TEST DATA

Test Group	Type of Surface Flaw in Rotating Band	Test Order	Seating Distance (in.)	Velocity (ft/sec)	Uncorrected Range (yds)	Corrected Range (yds)
11	None (Control Group)	3	48.0	2376	14326	15111
		16	(1)	2396	14413	15040
			Average	2386	14370	15075
[illegible]	[illegible]	17	(1)	2391	14391	15057
		7	[illegible]	2387	14423	15121
			Average	2389	14407	15089
[illegible]	One Nick [illegible]	[illegible]	[illegible]	2385	14453	15167
		19	(1)	2388	14328	15018
			Average	2387	14390	15092
[illegible]	[illegible]	[illegible]	(1)	2387	14416	15114
		13	(1)	2387	14349	15047
			Average	2387	14383	15080
[illegible]	[illegible]	11	[illegible]	2382	14429	15167
		[illegible]	48.0	2374	14269	15070
			Average	2378	14349	15118
[illegible]	[illegible]		[illegible]	2382	14394	15132
		[illegible]	[illegible]	2380	14344	15097
			[illegible]	2381	14369	15114
[illegible]	[illegible] deep	[illegible]	[illegible]	2390	14438	15113
		[illegible]	(1)	2391	14435	15101
			Average	2391	14437	15107
[illegible]	[illegible]	[illegible]	[illegible]	2394	14424	15067
		[illegible]	[illegible]	2384	14458	15181
			[illegible]	2389	14441	15124
[illegible]	[illegible]	6	[illegible]	2395	14502	15137
		15	(1)	2389	14330	15013
			Average	2392	14416	15075
[illegible]	[illegible]	[illegible]	[illegible]	2398	14488	15099
		[illegible]	[illegible]	2404	14493	15057
			Average	2401	14490	15078

[illegible] Distance Not Taken
[illegible] Date, 15 May 1974
[illegible] Propellant Index, [illegible] Propellant Temp = 90°F
[illegible] MARK [illegible] MOD 1, Serial No. [illegible]
[illegible] pounds

IV. ANALYSIS AND RESULTS

Figure 9 shows a plot of uncorrected range and velocity for the 10 test groups. These data are given in Table 1. Each point in Figure 9 is an average of two tests. The tests have been categorized as control, nicks, scratches, and gouges. Test groups are identified as discussed earlier in this report (T1-T10).

A statistical method (analysis of variance) was used to determine if there is a statistically significant difference between the 10 groups with respect to uncorrected range. The analysis of variance is given in Table 2 and was computed with a computer program described in reference (d). The computed F value in the analysis of variance table is much less than the Tabled F value even at the .90 significance level (a low probability level). Consequently, we are confident that there is no statistically significant difference between the 10 test groups with respect to uncorrected range. This enables us to conclude that the different types of damaged rotating bands did not give different uncorrected range. Although Figure 9 indicates there is a difference in uncorrected range for some test groups, this difference is not greater than the error within the groups as was shown in the analysis of variance table.

Figure 9 also shows the average velocity of the two projectiles of each test group. Note that the lowest and highest velocities correspond to the lowest and highest uncorrected range; this will be discussed later in this report.

An analysis of variance was conducted with the velocity data and is given in Table 3. The computed F value here is smaller than the Tabled F value for even the .90 significance level. Therefore, it can be concluded that there is no statistically significant difference in velocity for the 10 test groups and that the different types of rotating band damage do not affect velocity.

It can be seen from Figure 9 that the two test groups with rotating band gouges gave the highest velocity. Figure 10 offers an explanation for this condition. It shows that the projectiles with gouges in the rotating band did not seat in the gun as far as the other projectiles. The large gouge had the smallest seating distance. The small gouge had a larger seating distance than the large gouge but still less than the other projectiles. This decrease in seating distance was probably caused by the burrs of the rotating band gouges shown in Figures 7 and 8. Burrs such as shown here would prevent the projectile from being rammed into the gun the normal distance (as measured by seating distance) and would consequently cause a higher velocity. Reference (e) shows that there is an inverse relationship between seating distance and velocity as shown in Figure 10. Even though the analysis of variance of velocity showed that there is no significant difference in velocity for the different

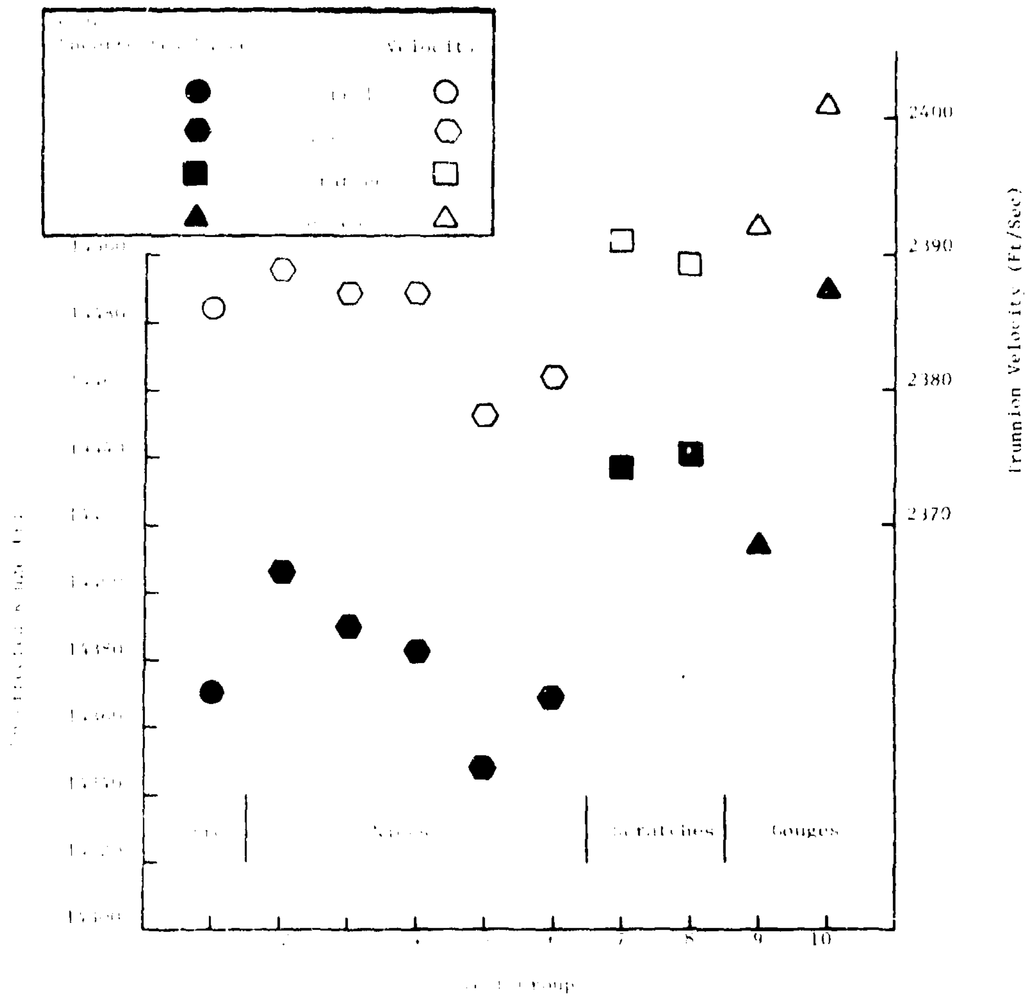

FIGURE 9

Average Uncorrected Range and Velocity for the Ten Test Groups

TABLE 2

ANALYSIS OF VARIANCE (UNCORRECTED RANGE)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Computed F Value	Tabled F Value	
Between Groups	32264	9	3584	0.82	$F_{.90}(9,10)$	2.35
Within Groups	43790	10	4379		$F_{.95}(9,10)$	3.02
					$F_{.99}(9,10)$	4.94
TOTAL	76054	19				

Hypothesis

H_o: All ten groups are equal

Conclusion H_o cannot be rejected since the Computed F Value is less than the Tabled F Value.

There is no statistically significant difference in the ten groups with respect to uncorrected range.

TABLE 3

ANALYSIS OF VARIANCE (VELOCITY)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Computed F Value	Tabled F Value
Between Groups	699	9	77.6	2.33	$F_{.90}$ (9,10) = 2.35
Within Groups	333	10	33.3		$F_{.95}$ (9,10) = 3.02
TOTAL	1032	19			$F_{.99}$ (9,10) = 4.94

Hypothesis

H_o: *All ten groups are equal*

Conclusion:

H_o cannot be rejected since the computed F value is less than the tabled F value.

There is no statistically significant difference in the ten groups with respect to velocity.

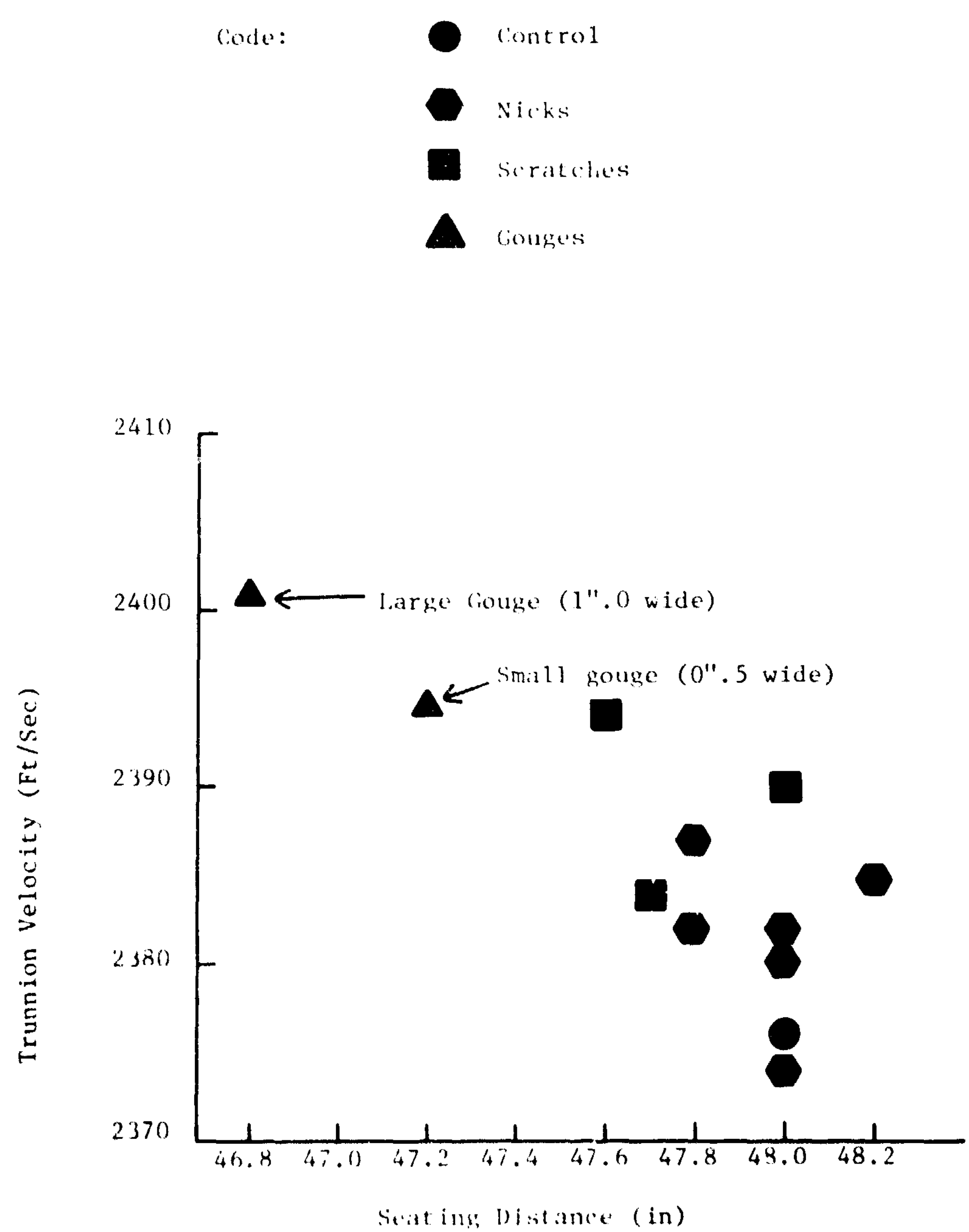

FIGURE 10

Relationship Between Velocity and Seating Distance for Projectiles with Damaged Rotating Bands

test groups; it is evident that burrs from gouges can cuase a decrease in seating distance and subsequent increase in velocity.

The uncorrected range was corrected for velocity and weather according to standard correction procedures. Weather correction was constant for all projectiles but velocity correction varied for different projectiles. It was especially necessary to correct for velocity variation after considering the earlier discussion on velocity.

Figure 11 shows the average corrected range for each of the 10 test groups. Note that the difference here between the test groups is much less than that for the uncorrected range shown in Figure 9. It can be seen from Figure 11 that the various test groups deviate very little from each other. The analysis of variance for corrected range is given in Table 4. It shows (because of the small computed F value) that there is no statistically significant difference between the 10 test groups with respect to corrected range which is the same conclusion as derived from analysis of uncorrected range data. This enables us to conclude that the different types of damaged rotating bands did not give different corrected range.

Dunnett's t statistic was also computed for the three sets of data (velocity, uncorrected range, and corrected range) and is given in Table 5. This statistic is described in reference (f). It is a good method to compare each of several treatments with a control treatment. In the case herein, there are nine groups (T2-T10) to be compared with a control group (T1). Table 5 gives Dunnett's t for the three sets of data and the formula for computing it. The hypotheses for this statistic are:

Ho: mean of group j=mean of control group
where $j = 2$ to 10

Ha: mean of group j≠mean of control group
where $j = 2$ to 10

Reject Ho if the Dunnett's t statistic is greater than or less than the critical values given in Table 5. Dunnett's t was not greater or less than the critical value for any of the comparisons in Table 5. Therefore, we can conclude the following:

a. Neither of groups 2-10 were different from the control group with respect to uncorrected range, velocity, or corrected range.

b. The damaged rotating bands did not influence the ballistic performance of projectiles for the test conditions studied in this report.

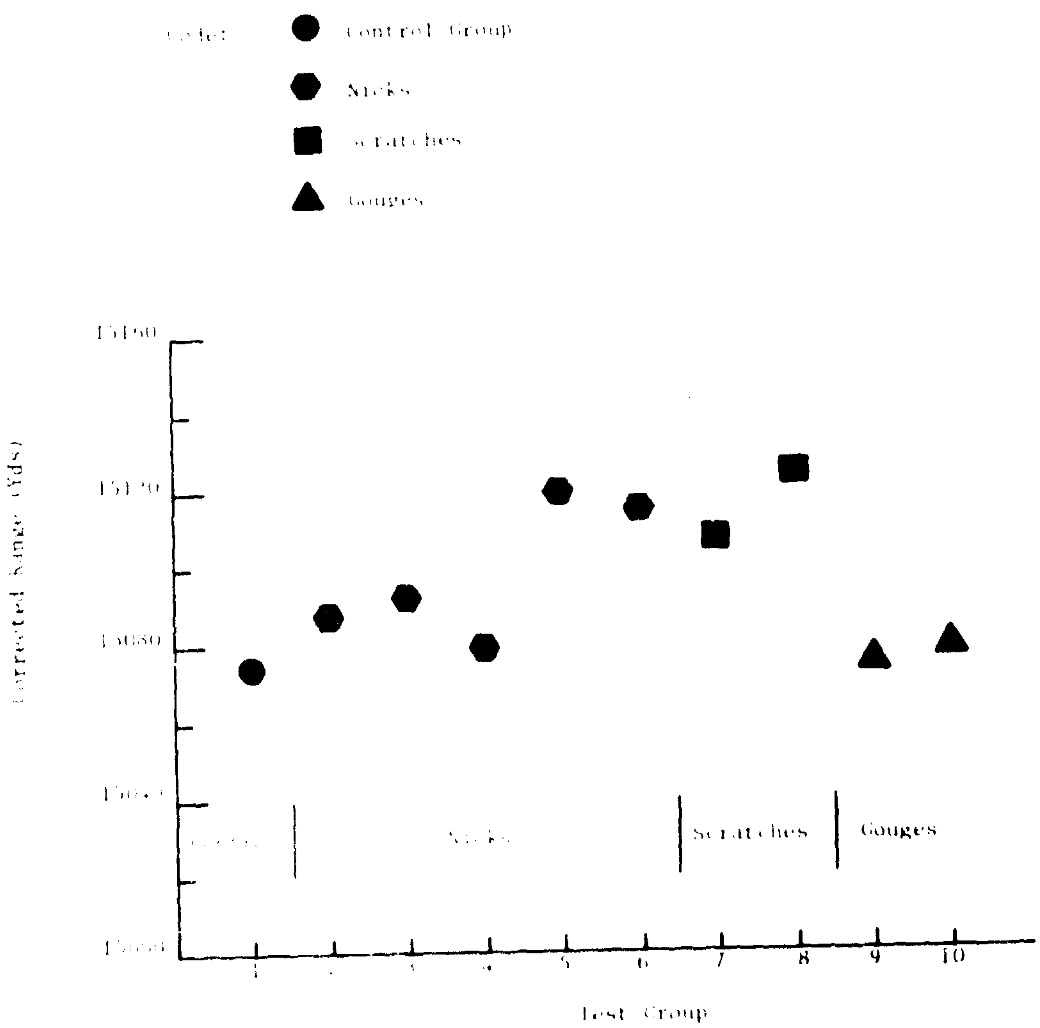

FIGURE 11

Average Corrected Range for the Ten Test Groups

TABLE 4

ANALYSIS OF VARIANCE (CORRECTED RANGE)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Square	Computed F Value	Tabled F Value
Between Groups	6474	9	719.3	0.19	$F_{.90}(9,10) = 2.35$
Within Groups	38370	10	3837.1		$F_{.95}(9,10) = 3.02$
TOTAL	44844	19			$F_{.99}(9,10) = 4.94$

Hypothesis

H_0: All ten groups are equal

Conclusion

H_o cannot be rejected since the Computed F Value is less than the Tabled F Value.

There is no statistically significant difference in the ten groups with respect to corrected range.

TABLE 5

Dunnett's t Statistic for Comparing Each Group with the Control Group for Uncorrected Range, Velocity, and Corrected Range

Group Compared with Control Group	Dunnett's t for Uncorrected Range	Dunnett's t for Velocity	Dunnett's t for Corrected Range
T2	0.56	0.52	0.22
T3	0.30	0.17	0.27
T4	0.20	0.17	0.08
T5	-0.32	-1.39	0.69
T6	-0.02	-0.87	0.63
T7	1.01	0.87	0.52
T8	1.07	0.52	0.79
T9	0.70	1.04	0.00
T10	1.81	2.60	0.05

Critical Values: $\alpha = .05$, $t = \pm 3.46$
$\alpha = .01$, $t = \pm 4.47$

Dunnett's t:

$$t = \frac{\bar{T}_j - \bar{T}_1}{\sqrt{2\ MS_{error}/N}}$$

where $\bar{T}_1$ = mean of control group

$\bar{T}_j$ = mean of group j, j = 2 to 10

MS_{error} = within group mean square from analysis of variance table

N = number of observations per group, two in this case

The D/R test acceptance limit is .70% for projectiles. The 20 projectiles tested herein had a D/R (corrected) of .26%. This also is indicative of the lack of difference in ballistic performance even though most of the rotating bands had damage of various degrees.

V. CONCLUSIONS

(1) It takes a serious damage in a rotating band to affect the ballistic performance of a projectile.

(2) Acceptance limits for damaged rotating bands are:

(a) No more than four dents or nicks up to 0.040 inch deep in the high lip are acceptable.

(b) No more than two scratches up to 0.070 inch deep x 1/8 inch wide aligned in the longitudinal direction of the projectile and covering the entire band length are acceptable.

(c) No more than one large gouge (1" x .047 deep) is acceptable.

(3) Gouges in a rotating band can decrease the projectile seating distance slightly and consequently increase velocity, but not to a significant level.

VI. RECOMMENDATIONS

(1) Results of this study should be used to determine acceptable limits and types of damage to rotating bands.

(2) Rotating band specifications should incorporate the results of this study where applicable.

(3) This information should be disseminated to loading depots, ships, and other necessary activities in order to prevent waste of projectiles.

(4) DCAS personnel at projectile manufacturing facilities should be advised of this study and its results.

APPENDIX A

REFERENCES

(a) SPCC msg R050820Z Apr 1974

(b) NWL spdltr EPD:JCN:bpc 8033/21 of 30 Apr 1974 to NAVORDSYSCOM (NAPEC)

(c) NWL spdltr EPD:ASJ:bpc 8033/21 of 29 May 1974 to NAVORDSYSCOM (NAPEC)

(d) Biomedical Computer Program; BMD01V Analysis of Variance, University of California, Los Angeles, April 1973 version

(e) J. S. O'Brasky, NWL Technical Report TR-3081, March 1974, "Investigation of Projectile Seating Distance Measurement as a Muzzle Velocity Calibration Technique"

(f) B. J. Winer, "Statistical Principles in Experimental Design", p.89, McGraw-Hill Book Company 1962

APPENDIX B

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18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Twenty 5"/54 MARK 64 MOD 0 projectiles with various degrees of rotating band damage were ballistic tested. A control group with no rotating band damage was tested along with several other groups with nicks, scratches, and gouges in the rotating bands. None of the groups gave ballistic results (velocity or range) significantly different from the control group or each other. Photographs show acceptable levels of rotating band damage with respect to ballistic performance.